CS621: Artificial Intelligence

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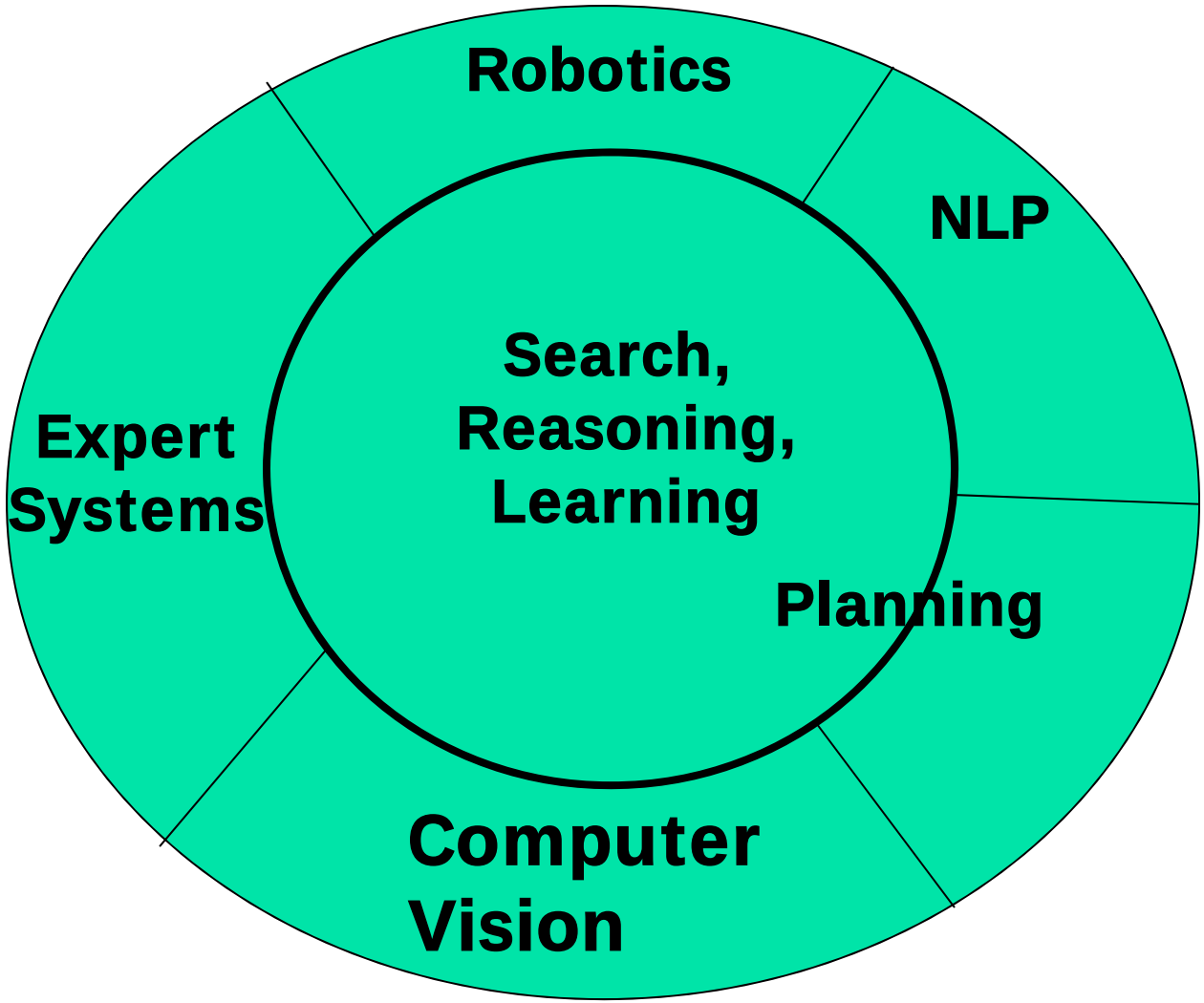
Lecture–1: Introduction

Persons involved

- Faculty instructor: Dr. Pushpak Bhattacharyya (www.cse.iitb.ac.in/~pb)
- TAs: *Prashanth, Debraj, Ashutosh, Nirdesh, Raunak, Gourab {pkamle, debraj, ashu, nirdesh, rpilani, roygourab}@cse*
- Course home page
  - www.cse.iitb.ac.in/~cs344-2010 (will be up)
- Venue: SIT Building: SIC301
- 1 hour lectures 3 times a week: Mon-11.30, Tue-8.30, Thu-9.30 (slot 4)
- Associated Lab: CS386- Monday 2-5 PM

Perspective

Disciplines which form the core of AI- inner circle
Fields which draw from these disciplines- outer circle.



Topics to be covered (1/2)

- **Search**
  - **General Graph Search, A***
  - **Iterative Deepening, α-β pruning, probabilistic methods**
- **Logic**
  - **Formal System**
  - **Propositional Calculus, Predicate Calculus, Fuzzy Logic**
- **Knowledge Representation**
  - **Predicate calculus, Semantic Net, Frame**
  - **Script, Conceptual Dependency, Uncertainty**

Topics to be covered (2/2)

- **Neural Networks: Perceptrons, Back Propagation, Self Organization**
- **Statistical Methods**
  - **Markov Processes and Random Fields**
    - **Computer Vision, NLP, Machine Learning**
- **Planning: Robotic Systems**

==========(if possible)

- **Anthropomorphic Computing: Computational Humour, Computational Music**
- **IR and AI**
- **Semantic Web and Agents**

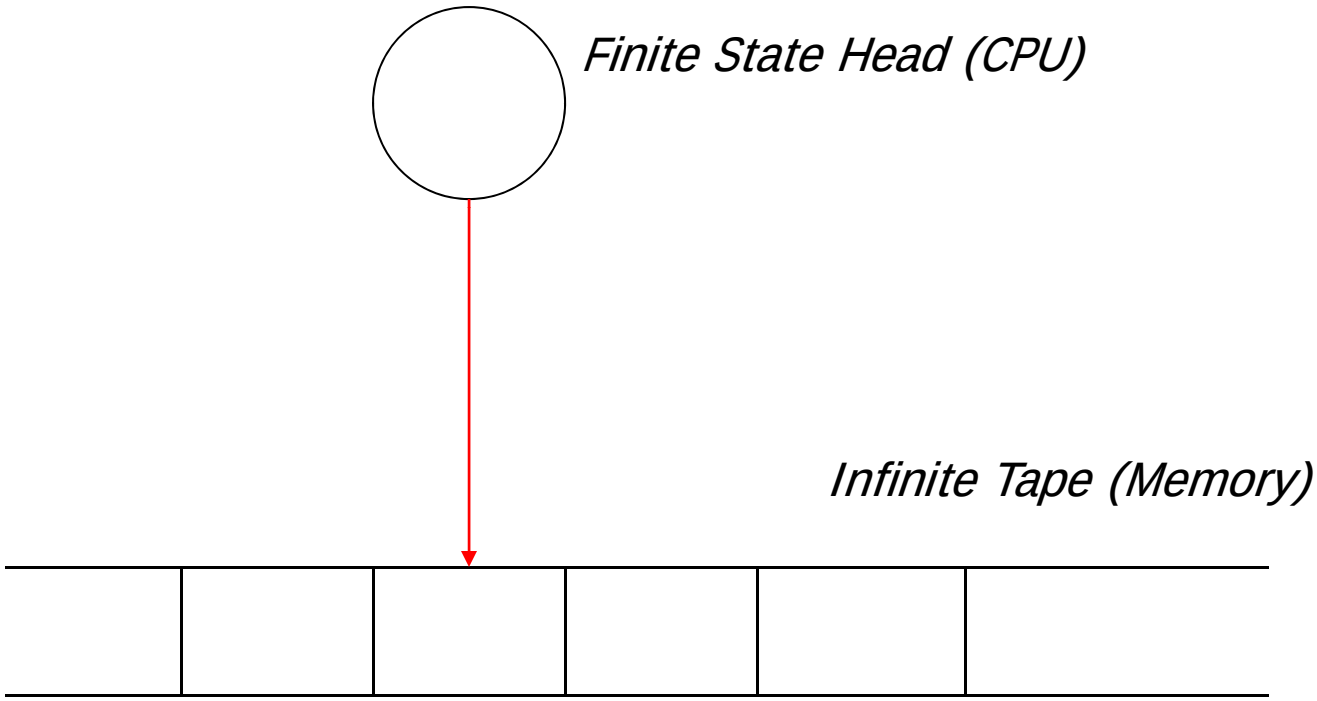
Resources

- Main Text:
  - Artificial Intelligence: A Modern Approach by Russell & Norvik, Pearson, 2003.
- Other Main References:
  - Principles of AI - Nilsson
  - AI - Rich & Knight
  - Knowledge Based Systems – Mark Stefik
- Journals
  - AI, AI Magazine, IEEE Expert,
  - Area Specific Journals e.g, Computational Linguistics
- Conferences
  - IJCAI, AAAI

Foundational Points

- Church Turing Hypothesis
  - Anything that is computable is computable by a Turing Machine
  - Conversely, the set of functions computed by a Turing Machine is the set of ALL and ONLY computable functions

Turing Machine



Foundational Points *(contd)*

- Physical Symbol System Hypothesis (Newel and Simon)
  - *For Intelligence to emerge it is enough to manipulate symbols*

Foundational Points *(contd)*

- Society of Mind (Marvin Minsky)
  - *Intelligence emerges from the interaction of very simple information processing units*
  - *Whole is larger than the sum of parts!*

Foundational Points *(contd)*

- Limits to computability
  - *Halting problem: It is impossible to construct a Universal Turing Machine that given any given pair <M, I> of Turing Machine M and input I, will decide if M halts on I*
  - What this has to do with intelligent computation? *Think!*

Foundational Points *(contd)*

- Limits to Automation
  - *Godel Theorem: A "sufficiently powerful" formal system cannot be BOTH complete and consistent*
  - "Sufficiently powerful": at least as powerful as to be able to capture Peano's Arithmetic
  - Sets limits to automation of reasoning

Foundational Points *(contd)*

- Limits in terms of time and Space
  - *NP-complete and NP-hard problems: Time for computation becomes extremely large as the length of input increases*
  - *PSPACE complete*: Space requirement becomes extremely large
  - Sets limits in terms of resources

Two broad divisions of Theoretical CS

- Theory A
  - Algorithms and Complexity
- Theory B
  - Formal Systems and Logic

AI as the forcing function

- Time sharing system in OS
  - Machine giving the illusion of attending simultaneously with several people
- Compilers
  - Raising the level of the machine for better man machine interface
  - Arose from Natural Language Processing (NLP)
    - NLP in turn called the forcing function for AI

Allied Disciplines

Philosophy	Knowledge Rep., Logic, Foundation of AI (is AI possible?)
Maths	Search, Analysis of search algos, logic
Economics	Expert Systems, Decision Theory, Principles of Rational Behavior
Psychology	Behavioristic insights into AI programs
Brain Science	Learning, Neural Nets
Physics	Learning, Information Theory & AI, Entropy, Robotics
Computer Sc. & Engg.	Systems for AI

Grading

- (i) Exams
  - Midsem
  - Endsem
  - Class test
- (ii) Study
  - Seminar (in group)
- (iii) Work
  - Lab Assignments (cs386; in group)

Fuzzy Logic

Fuzzy Logic tries to capture the human ability of reasoning with imprecise information

- Models Human Reasoning
- Works with imprecise statements such as:

  In a process control situation, "*If* the temperature is moderate and the pressure is high, *then* turn the knob slightly right"
- The rules have "Linguistic Variables", typically adjectives qualified by adverbs (adverbs are hedges).

Underlying Theory: Theory of Fuzzy Sets

- Intimate connection between logic and set theory.
- Given any set ‘S’ and an element ‘e’, there is a very natural predicate, $\mu_s(e)$ called as the *belongingness predicate*.
- The predicate is such that,

$$\mu_s(e) = 1, \quad \text{iff } e \in S$$
$$= 0, \quad \text{otherwise}$$

- For example, $S = \{1, 2, 3, 4\}$, $\mu_s(1) = 1$ and $\mu_s(5) = 0$
- A predicate $P(x)$ also defines a set naturally.

  $S = \{x \mid P(x) \text{ is } true\}$

  For example, $even(x)$ defines $S = \{x \mid x \text{ is even}\}$

Fuzzy Set Theory (contd.)

- Fuzzy set theory starts by questioning the fundamental assumptions of set theory *viz.*, the belongingness predicate, μ, value is 0 or 1.
- Instead in Fuzzy theory it is assumed that,

  $\mu_s(e) = [0, 1]$
- Fuzzy set theory is a generalization of classical set theory also called Crisp Set Theory.
- In real life *belongingness* is a fuzzy concept.

  Example: Let, T = set of "tall" people

  μ_T(Ram) = *1.0*

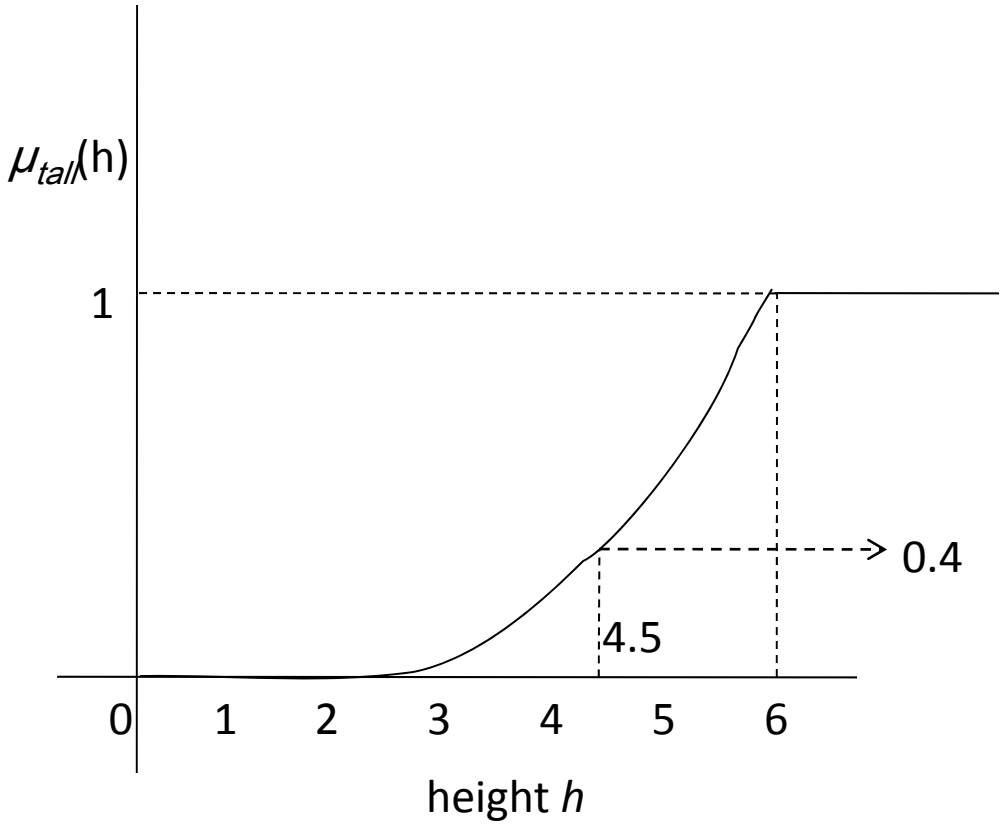
  μ_T(Shyam) = *0.2*

  Shyam belongs to T with degree *0.2*.

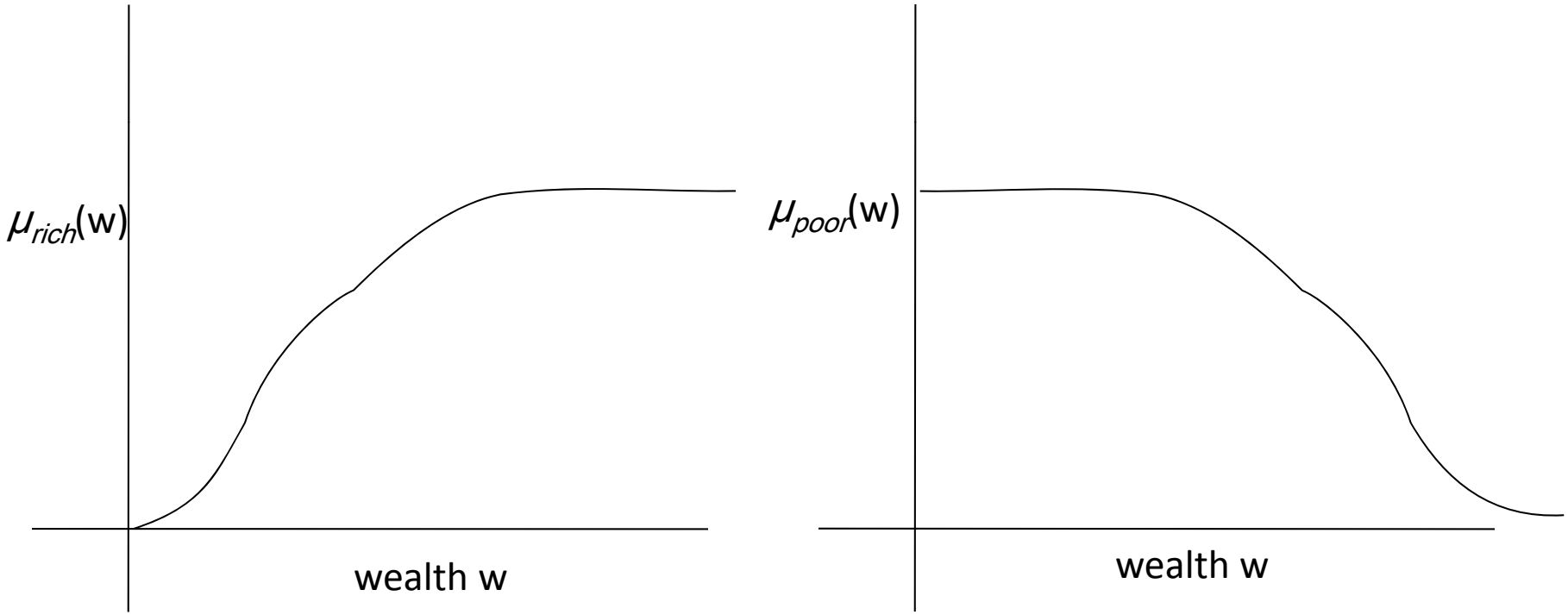
Linguistic Variables

- Fuzzy sets are named by Linguistic Variables (typically adjectives).
- Underlying the LV is a numerical quantity

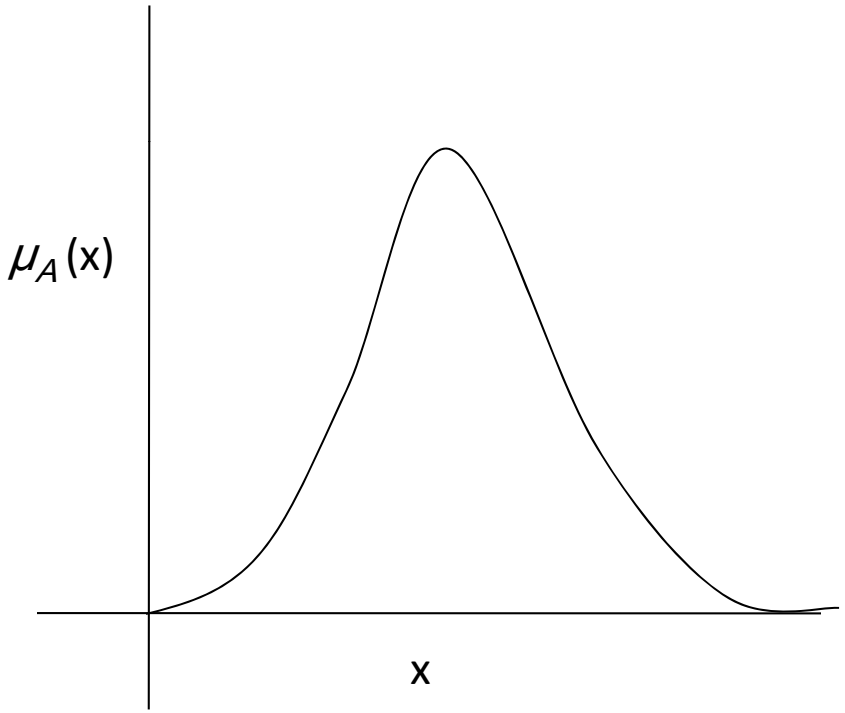
  E.g. For ‘tall’ (LV), ‘height’ is numerical quantity.
- Profile of a LV is the plot shown in the figure shown alongside.



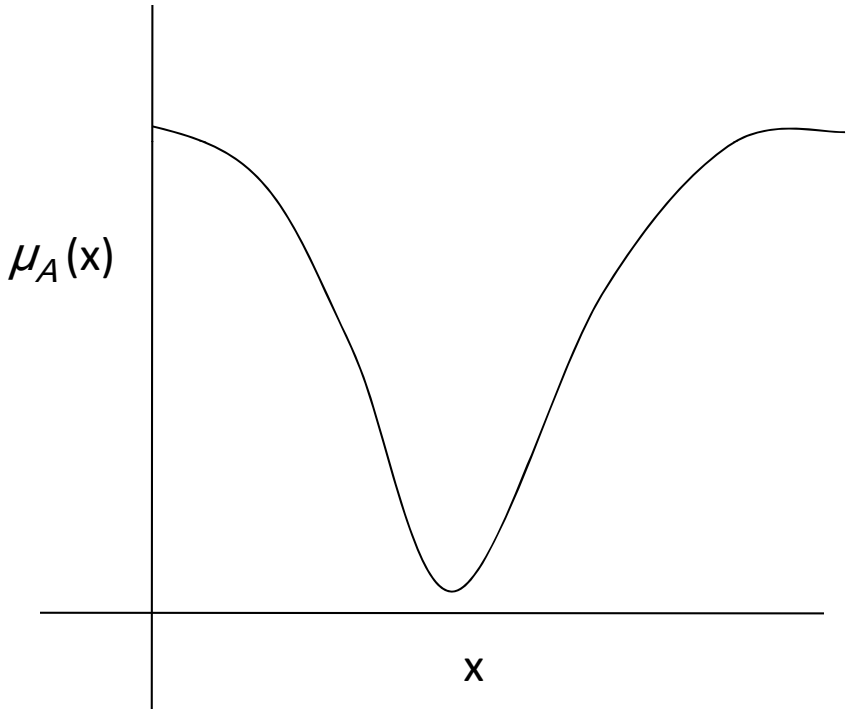
Example Profiles



Example Profiles



Profile representing
moderate (*e.g.* moderately rich)



Profile representing
extreme

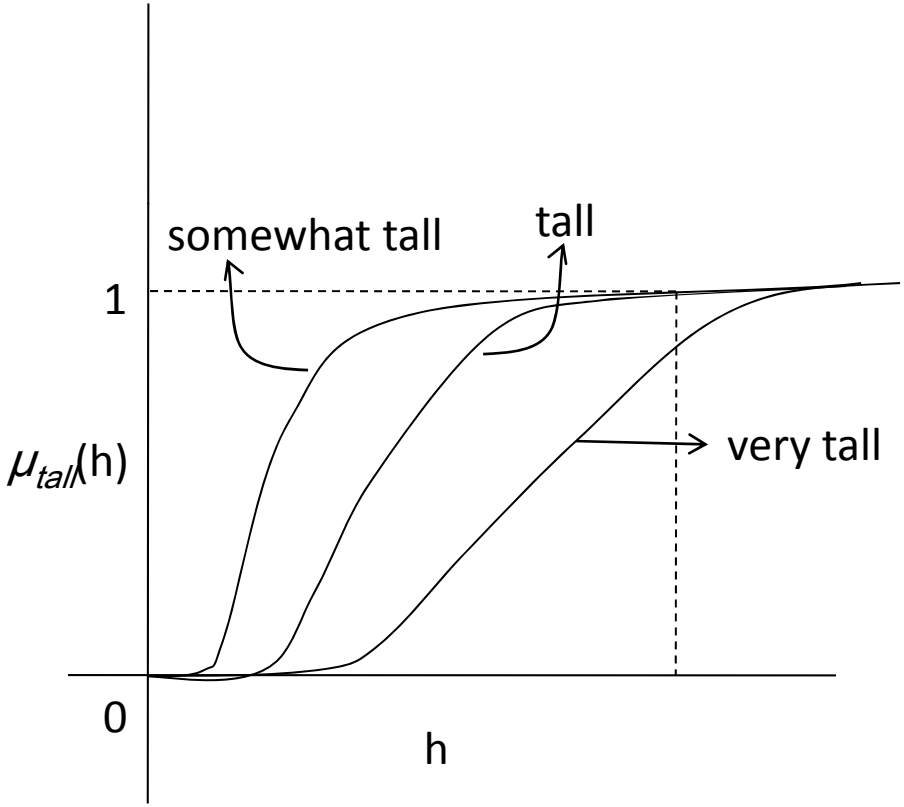
Concept of Hedge

- Hedge is an intensifier
- Example:

  LV = tall, LV_1 = very tall, LV_2 = somewhat tall
- 'very' operation:

  $\mu_{very\ tall}(x) = \mu^2_{tall}(x)$
- 'somewhat' operation:

$\mu_{somewhat\ tall}(x) = \sqrt{(\mu_{tall}(x))}$



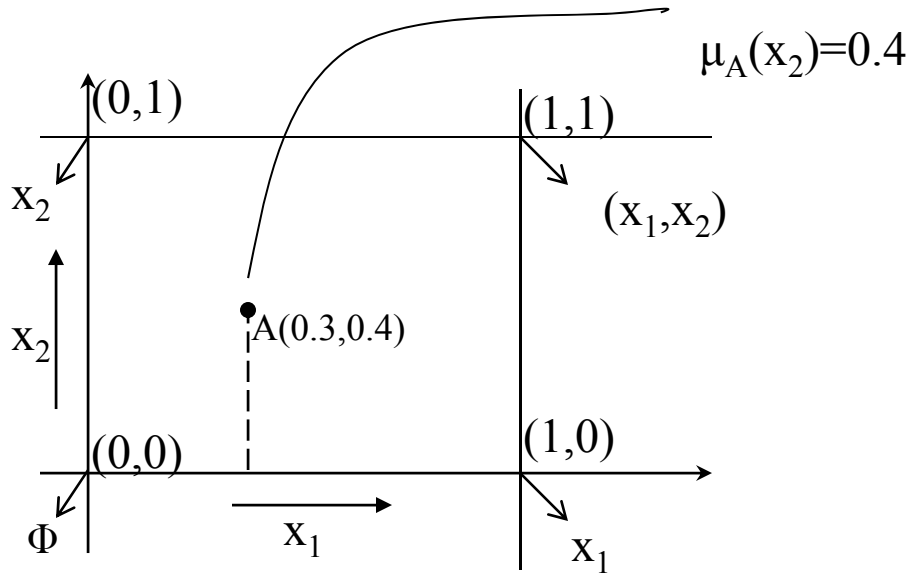
Representation of Fuzzy sets

Let $U = \{x_1, x_2, \ldots\ldots, x_n\}$

$|U| = n$

The various sets composed of elements from U are presented as points on and inside the n-dimensional hypercube. The crisp sets are the corners of the hypercube.

$U = \{x_1, x_2\}$



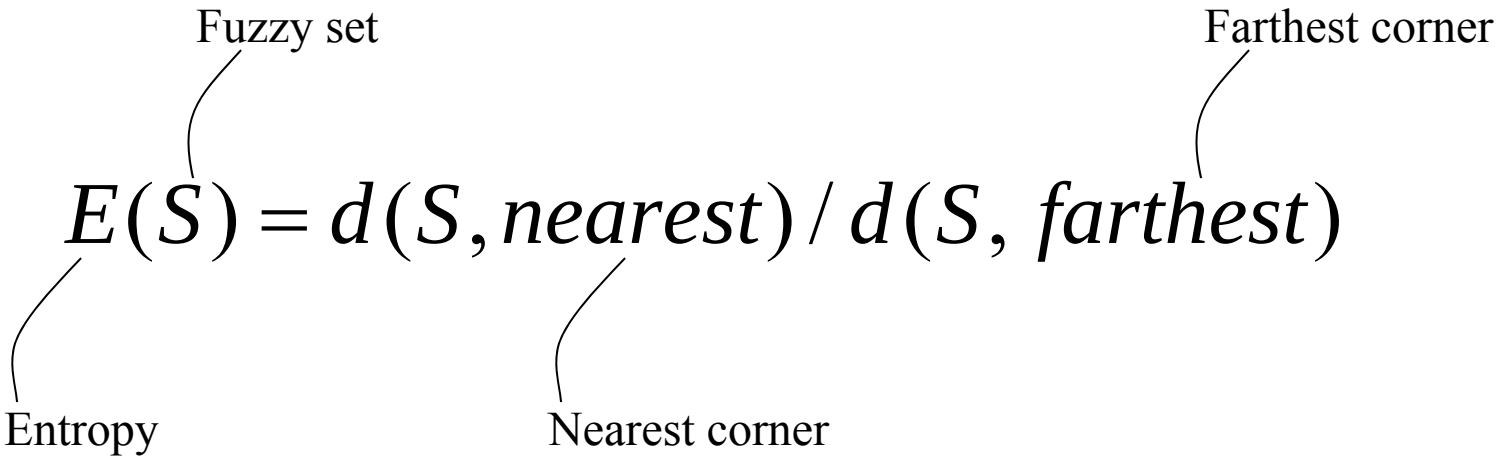
A fuzzy set A is represented by a point in the n-dimensional space as the point $\{\mu_A(x_1), \mu_A(x_2), \ldots\ldots \mu_A(x_n)\}$

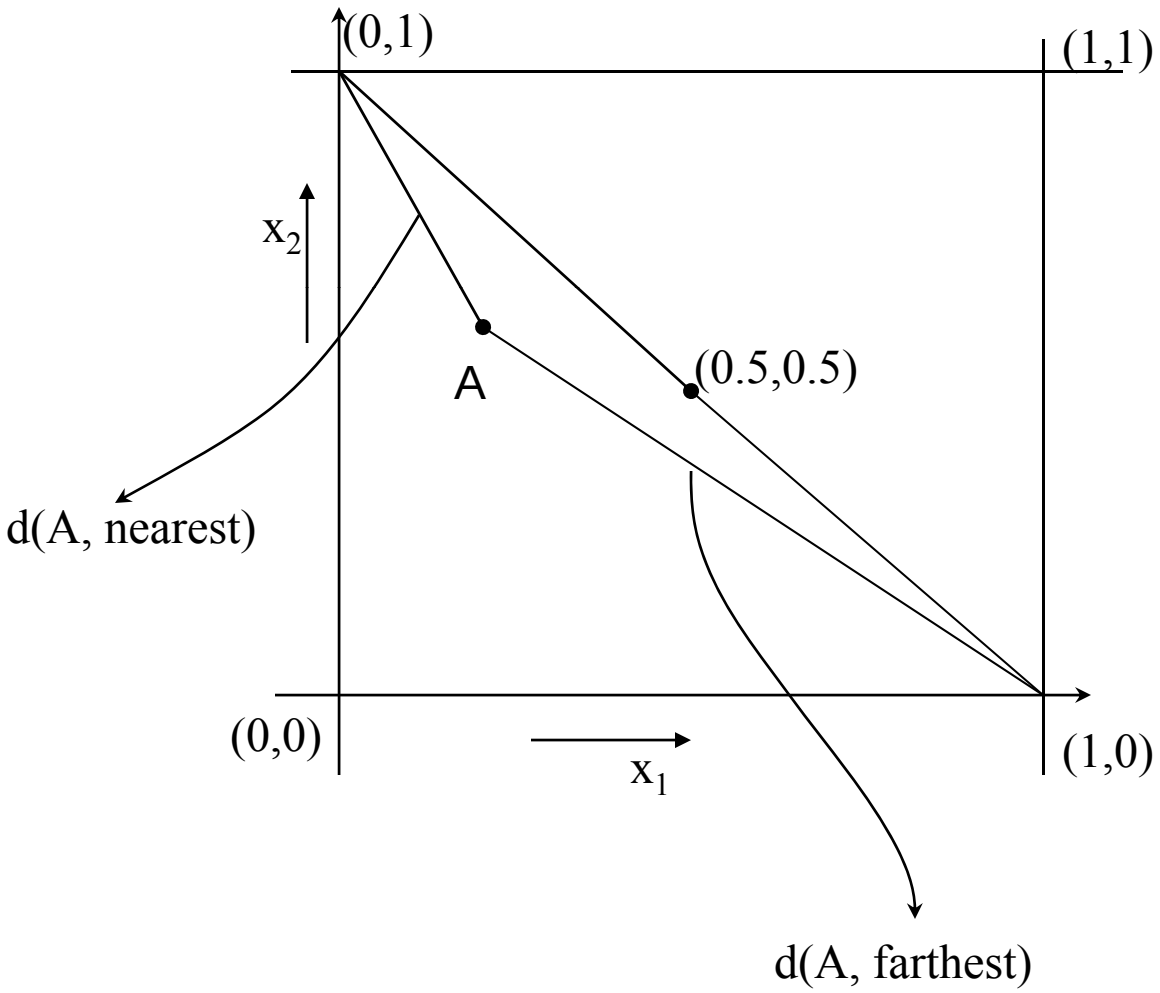
Degree of fuzziness

The centre of the hypercube is the "most fuzzy" set. Fuzziness decreases as one nears the corners

Measure of fuzziness

Called the entropy of a fuzzy set




(0,1)
(1,1)
x2
A
(0.5,0.5)
d(A, nearest)
(0,0)
x1
(1,0)
d(A, farthest)

Definition

Distance between two fuzzy sets

$$d(S_1, S_2) = \sum_{i=1}^{n} \underbrace{| \mu_{s_1}(x_i) - \mu_{s_2}(x_i) |}_{L_1 \text{ - norm}}$$

Let C = fuzzy set represented by the centre point

d(c,nearest) = |0.5-1.0| + |0.5 – 0.0|

= 1

= d(C,farthest)

=> E(C) = 1

Definition

Cardinality of a fuzzy set

$$m(s) = \sum_{i=1}^{n} \mu_s(x_i)$$ [generalization of cardinality of classical sets]

Union, Intersection, complementation, subset hood

$$\mu_{s_1 \cup s_2}(x) = \max[\mu_{s_1}(x), \mu_{s_2}(x)] \forall x \in U$$

$$\mu_{s_1 \cap s_2}(x) = \min[\mu_{s_1}(x), \mu_{s_2}(x)] \forall x \in U$$

$$\mu_{s^c}(x) = 1 - \mu_s(x)$$

Note on definition by extension and intension

$S_1 = \{x_i | x_i \bmod 2 = 0 \}$ – Intension

$S_2 = \{0,2,4,6,8,10,\ldots\ldots\ldots\}$ – extension

How to define subset hood?